What we claim as our invention is:

1. A set of methods, functions and apparatus for bulk and other general material handling such as loading, unloading, and transportation by mobile robots in the form of autonomous vehicles and machines, for industrial applications in limited areas and fields, outdoor as well as indoor or underground, comprising:

- a method with one or more loading zones as the only kind of areas from which loading and its constituent material volume penetration by the vehicle's bucket is allowed, one or more unloading zones as the only kind of areas to which unloading and its constituent bucket emptying is allowed, and one or more obstacle free zones which, together with loading and unloading zones, are the only kind of areas where autonomous navigation and vehicle implement movements are allowed;

- a method with a reference ground surface supporting material volumes and other general handling objects, where such a surface, specifically in the loading, unloading and obstacle free zones is accurately defined, in a fixed to ground coordinate system, by x, y and z-coordinates for ordered surface points, and used as reference for comparisons with current measurements of the surface of stored material volumes and other general handling objects thereon , and where this data is employed for accurate vehicle path and vehicle and implement motion parameter optimization at loading and unloading operations;

- a position determination system for accurately determining, in real time, outdoor as well as indoor or underground, the three-dimensional position x, y, and z and the three attitude angles heading, pitch and roll, of a fixed to vehicle coordinate system, in a fixed to ground coordinate system, where this position determination system can be a laser-optic system where the position is determined by means of azimuth and elevation angle measurements, with an on-board vehicle located rotating laser-optic sensor, in the fixed to vehicle coordinate system, to a number of reflectors with known coordinates in the fixed to ground coordinate system;

- a terrain surface measuring system for determining, in real time, the three-dimensional position of points on the terrain surface in a fixed to ground coordinate system, where the position of each such point can be determined by means of azimuth angle and range measurements in a fixed to vehicle coordinate system by at least one on-board vehicle located scanning laser rangefinder, and coordinate transformation of such measurements employing the six degrees of freedom position data in fixed to ground coordinates from the position determination system;

- a dynamic terrain model for collecting, processing and updating terrain surface data employed for optimizing vehicle path and vehicle and bucket movement parameters in loading and unloading operations by measuring the location and shape of material volumes and obstacles, where this model has at least three essential layers: 1) developing model based on measurements from the current path with the laser-optic terrain surface measuring system, 2) best estimate of reference ground surface based on geodetic data or earlier runs with the system over the actual terrain and 3) the best estimate of the terrain surface of the total worksite attainable by the system, where this dynamic terrain model is analysed for determining attack, and bucket emptying points, and the position of the vehicle at loading and unloading, respectively, and also a loading height profile of the material volume along the loading path in a loading operation;

- a mission computer provided with software for optimizing dynamic vehicle paths and the movements of vehicle and load handling implement during loading and unloading operations based on attack, bucket emptying, loading and unloading points and loading height profile data from the dynamic terrain model, and with mission instructions comprising data for defining obstacle free, loading and unloading zones, parameters for static and dynamic transportation paths, reconnaissance paths, loading paths and unloading movements and mission programs for selecting and linking paths and for generating detailed vehicle and implement control data lists for low level vehicle control based on the current vehicle path and vehicle and implement movement parameters;

- a vehicle control computer for low level vehicle control based on a vehicle and implement control data list from the mission computer, and provided with interfaces to the sensors and actuators as needed for controlling the vehicle and its implements.

2. A set of methods, functions and apparatus as set forth in claim 1 wherein the dynamic terrain model also is used for evaluating planned paths and for obstacle detection in order to avoid the vehicle running into obstacles or outside the specific areas devoted for autonomous navigation, comprising:

- a layer in the dynamic terrain model for indicating obstacle free terrain elements;

- a method to classify an element No. n in the dynamic terrain model as representing a not obstacle-free part of the terrain by comparing $Z(1,n)$ of the developing model layer in the dynamic terrain model with the a priori best estimate $Z(3,n)$ of the terrain surface layer, if $H < Z(1,n) - Z(3,n)$ where H is a given maximum obstacle height;

- a method for evaluating planned paths concerning the risk of the vehicle for stepping outside the specific areas devoted for autonomous navigation, in order to detect possible planning errors by testing, for all elements n of the dynamic terrain model representing points in each obstacle avoidance mapping for the vehicle's planned path, if such a point not is inside any of the loading, unloading or obstacle free zones, then the planned path is rejected, where;
  - ◊ a number of vehicle obstacle avoidance zones are defined in a fixed to vehicle coordinate system;
  - ◊ a specific obstacle avoidance action can be assigned to a vehicle obstacle avoidance zone;
  - ◊ obstacle avoidance zone projection is a momentarily defined area in a fixed to ground coordinate system where this area constitutes the projection in the horisontal plane of a fixed to vehicle obstacle avoidance zone for one specific position of the vehicle in its path;
  - ◊ obstacle avoidance mapping in fixed to ground coordinates is a union set of obstacle avoidance zone projections for a sequence of positions of the vehicle in its path;
- a method, for obstacle avoidance action, based on the presence of a non obstacle-free terrain element No. n of the dynamic terrain model inside any vehicle obstacle avoidance zone projection for the vehicle's present position, to cause an alarm specific to the kind of action relevant for this obstacle avoidance zone projection.
- a method, for obstacle avoidance action, based on the presence of a non obstacle-free terrain element No. n of the dynamic terrain model inside any obstacle avoidance mapping representing the vehicle's planned path, from the vehicle's present position, to cause an alarm specific to the kind of action relevant for this obstacle avoidance mapping;

3. A set of methods, functions and apparatus as set forth in claim 1 wherein the dynamic terrain model also is used for optimizing parameters for controlling the vehicle's path and the vehicle's and the load handling implement's movements when approaching and penetrating a material volume in a loading operation, comprising:

- a method to select an attack point for the bucket's entry in a material volume at the coordinates of the nearest terrain element n to a line in front of, and parallell with, the intended front of the material volume where on this element the material volume height $Z(1,n)$ - $Z(2,n)$ exceeds a given value A;
- a method to optimize the loading operation in the form of vehicle path and bucket movement parameters at the outset of a loading operation by estimating loaded volume as a function of

penetration depth and bucket lift and tilt movement parameters and thereby, from a loading height profile of the current terrain surface defined for a number of points i =1, 2, 3, ... along the planned loading path, where the Z-coordinate $Z_{load}(i)$ in a fixed to ground coordinate system for each such point No. i represents an average of $Z(1,n)$ for points n in a representative to the bucket width neighbourhood of such point No. i from the developing model layer of the dynamic terrain model, where this loaded volume is calculated as the volume cut out by the bucket for a succession of positions, in the same fixed to ground coordinate system, of the vehicle and the bucket for given movement parameters of vehicle and bucket movement;

- a method to reduce friction caused by reaction forces from ground acting on the bucket, in the bucket's penetration of a material volume by optimizing the hydraulic pressure to the bucket lift and tilt cylinders based on an estimate of the total weight and momentum of the load handling implement with its bucket and its loaded volume as a function of penetration depth and bucket lift and tilt movement parameters.